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Warfighter-in-the-Loop Experiments with GT-DRIVE and SimCreator

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OUTLINE

- Motivation - Hybrid Electric Vehicle Evaluation and Assessment Program
- TARDEC Duty Cycle Experiment Process (DCE-TOP)
    - Warfighter-in-the-Loop
- TARDEC GT-Drive Conv. & Hybrid HMMWV Models
- SimCreator Vehicle Dynamics Model
- GT-DRIVE / SimCreator Integration
- DCE-TOP Results
- Conclusion

MOTIVATION

- Develop HEV Test Operating Procedure (TOP) for Military Vehicles
- Determine the fuel economy benefits of hybrid electric vehicles using quantifiable test data
- Provides Test Data to Validate TARDEC DCE-TOP Simulations

HEVEA Testing:

Conventional:

- 2 - HMMWVs,
- 2 -21/2T LMTVs
- 1 - 5T MTV
- 1 – FMTV CVT
- 2 - HEMTTS
- 1 – AM GEN UV

Hybrid Electric:

- 1 – HMMWV
- 1 – RSTV
- 1 - IMG UV
- 1 – LM UV
- 1 – AH/SS MSV
- 1 – BAE FMTV
- 1 – OSHKOSH HEMTT “A3”

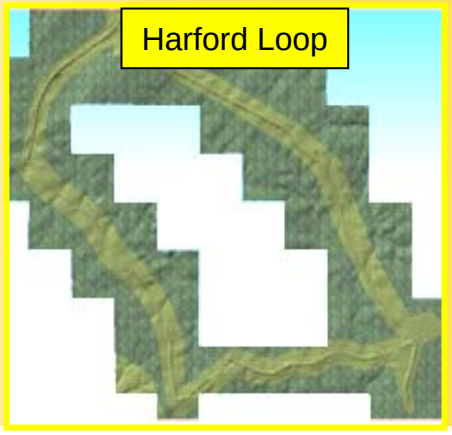
RSTV Series HE

Parallel Hybrid MSV

2 Parallel hybrid UV’s

TARDEC Duty Cycle Experiment Process DCE-TOP (Feb 2007)

- Purpose
  - Replicate Field Tested Fuel Economy Measurements
  - Driver-in-the-Loop, Digitized Test Courses
  - Vehicle Models, Motion Platform
- HMMWV Vehicles
  - M1113 Conventional
  - XM1124 Hybrid
- Participants
  - 2 APG Test Drivers
- Aberdeen Terrains
  - Harford Loop
  - Munson SFC
  - Churchville B
  - Perryman Paved
- Variables
  - Terrain
  - Vehicle Speed
  - Driver
  - Initial SOC (Hybrid)



HMMWV Power-Train Components

M1113 Conventional:

- GM / GEP 6.5 L Turbo-Diesel
  - 145 kW @ 3200 rpm
- GM 4L80-E Automatic Trans.
  - 4 Spd. Overdrive
  - Conv. Lockup 3rd & 4th
- 2-Spd. Transfer-Case

XM1124 Series Hybrid:

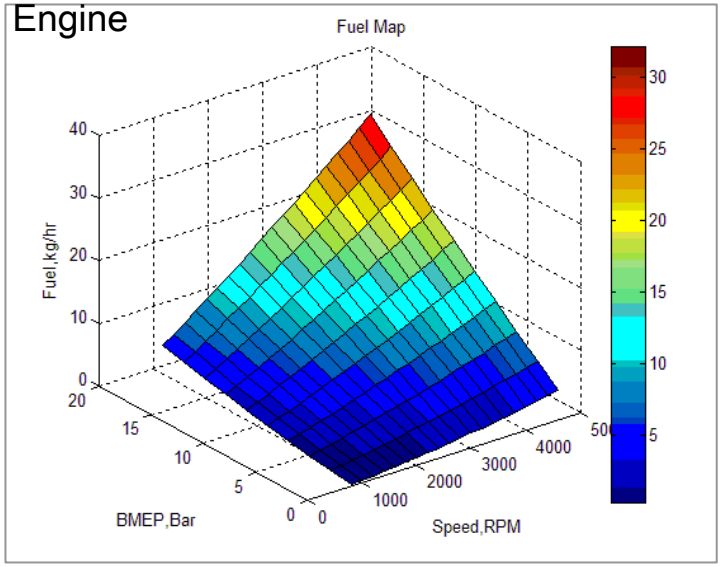
- Peugeot 2.2 L Turbo-Diesel
  - 100 kW @ 4000 rpm
- UQM SR-286 PM Generator
  - 85 kW Cont Output
- Saft VL30P LiOn Battery Pack
  - 300 V, 60Amp-Hr
- UQM SR-286 Traction Motors
  - 550 N-M Peak Torque

Common Components:

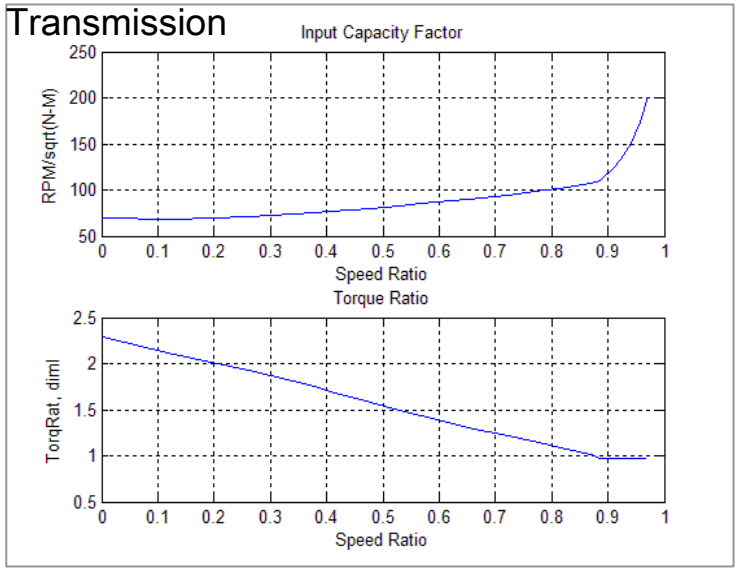
- Torsen Differentials
- Reduction Hubs (1.92:1)

GT-Drive Model Input Data Sets

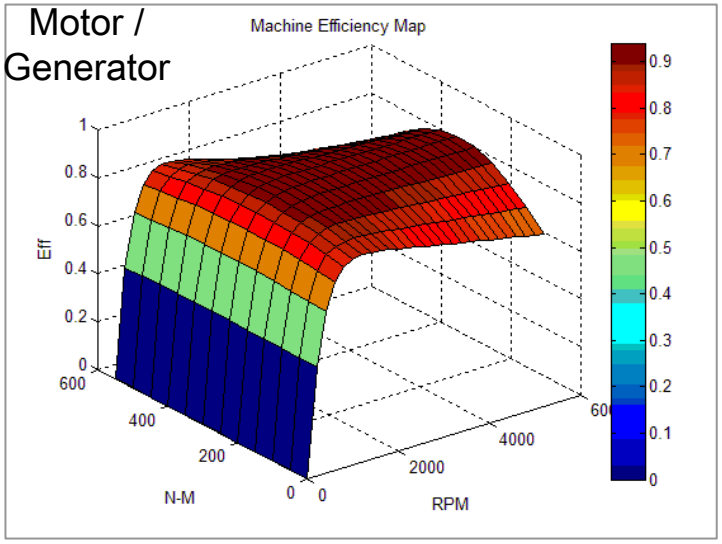
Engine



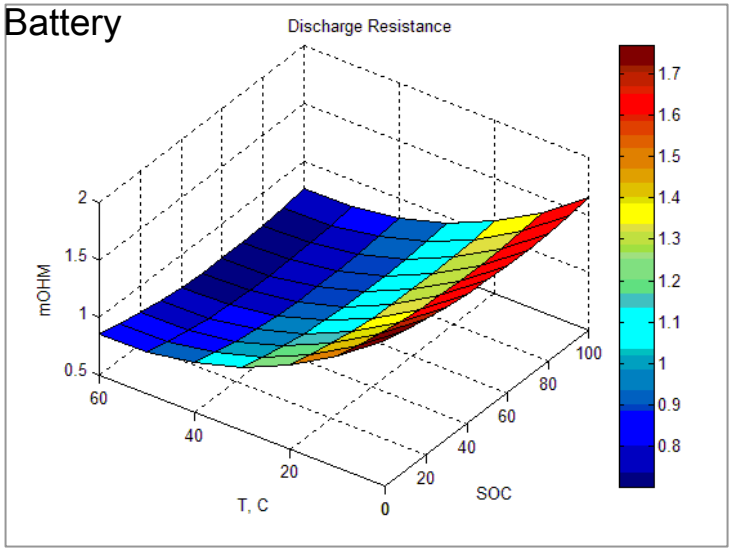
Transmission



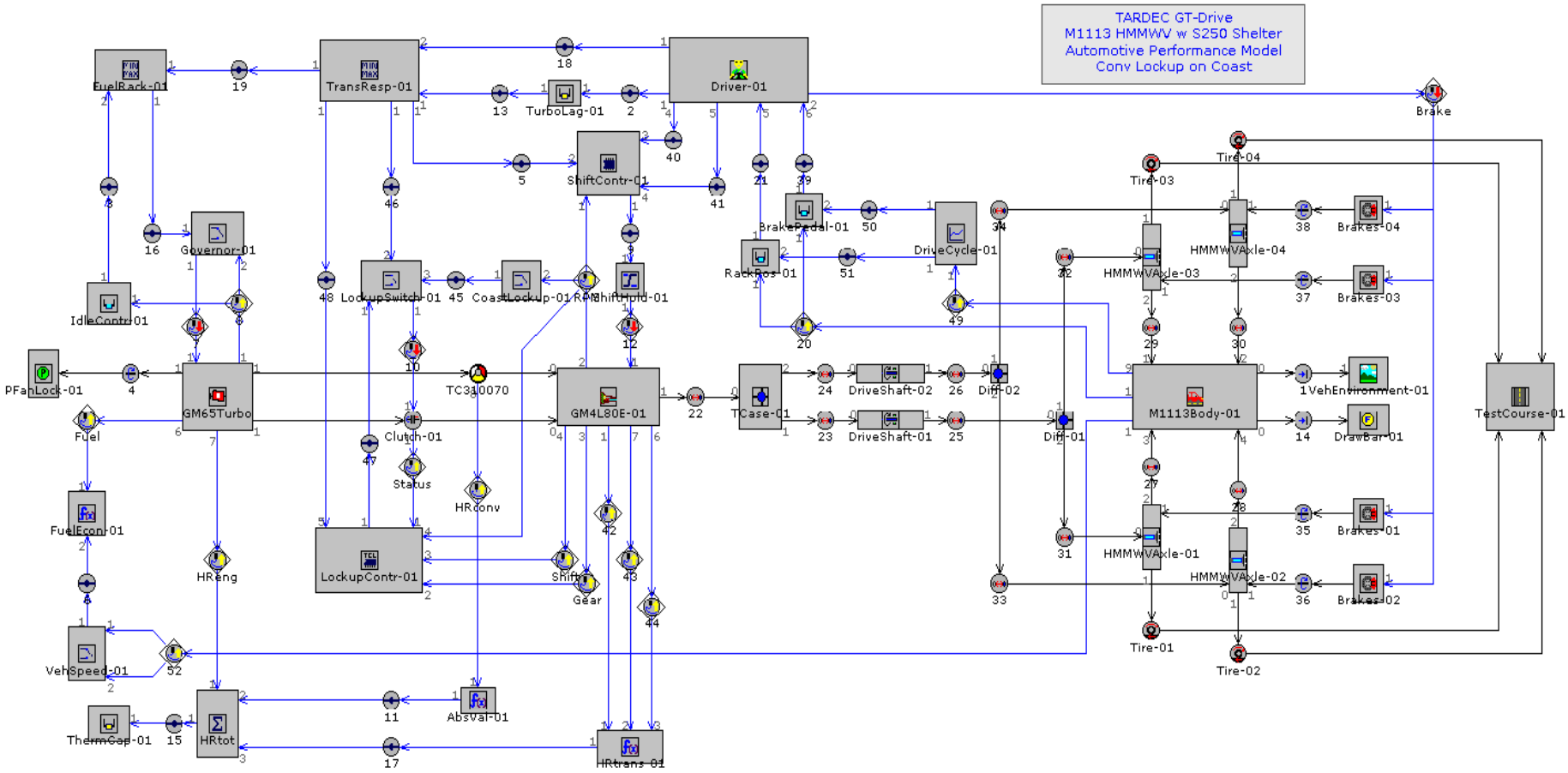
Motor / Generator



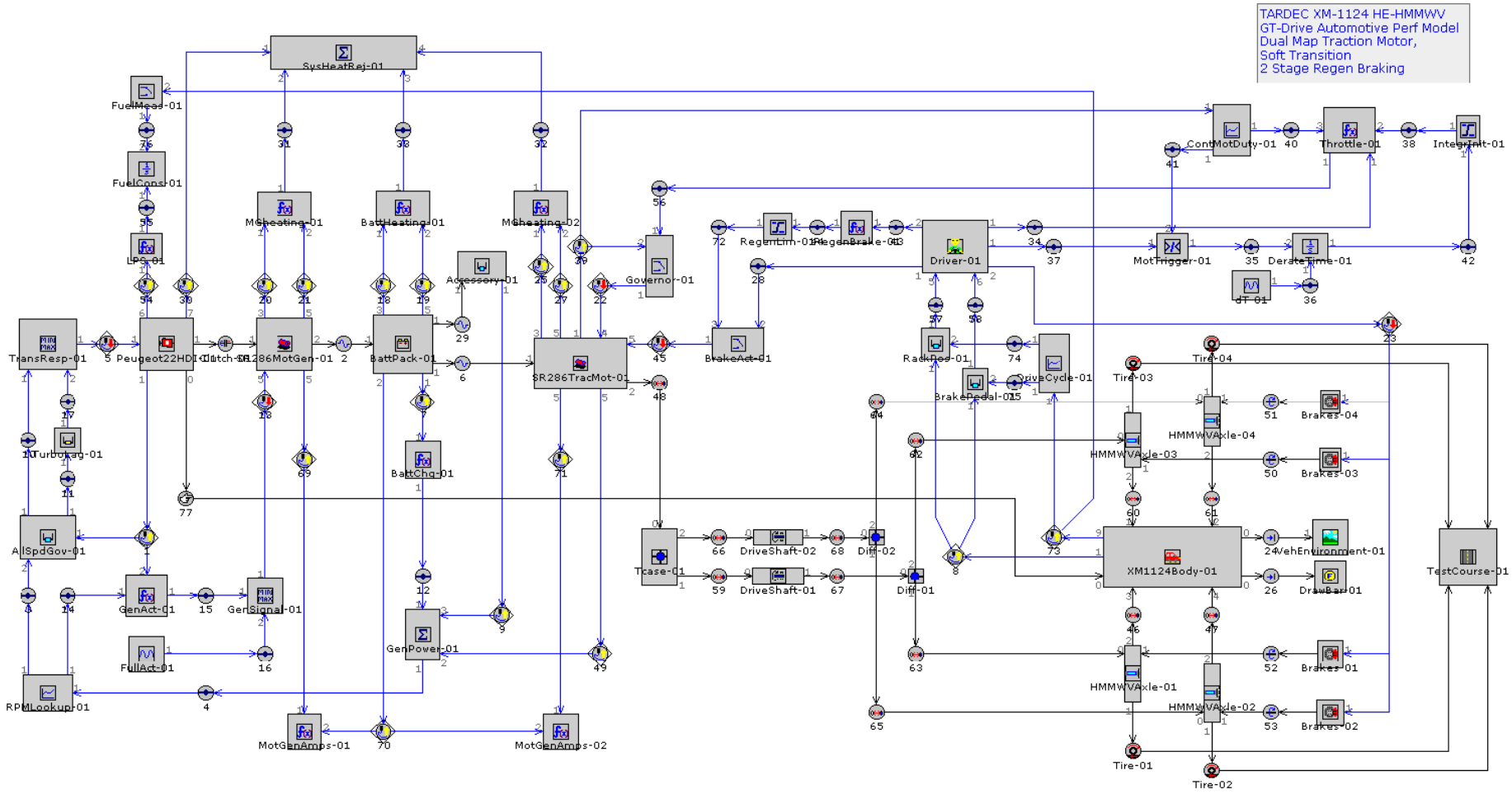
Battery



GT-Drive M1113 Conventional HMMWV Vehicle Model



GT-Drive XM1124 Hybrid HMMWV Vehicle Model



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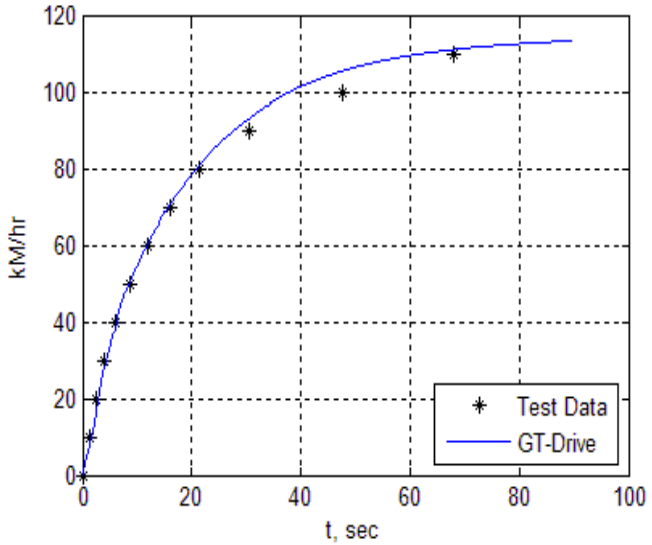
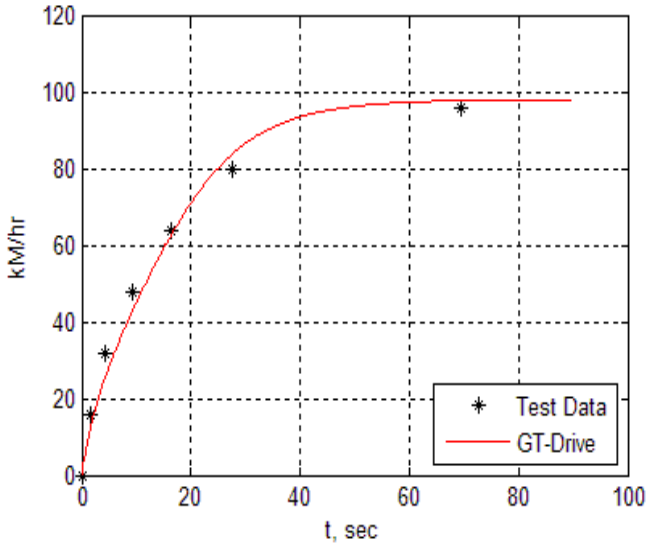
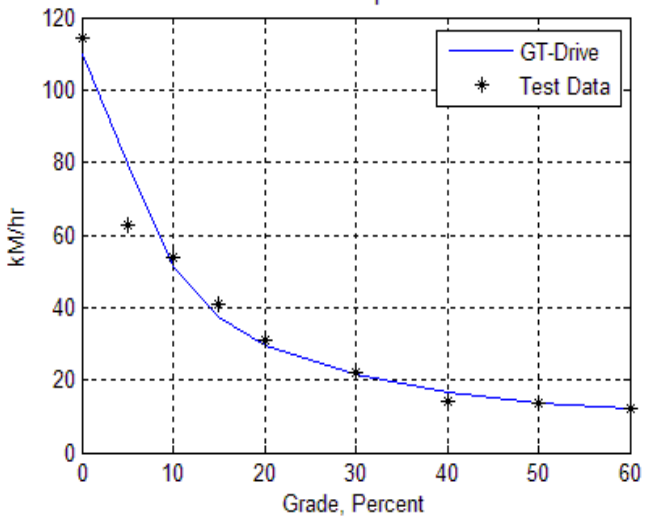
GT-Drive Vehicle Performance

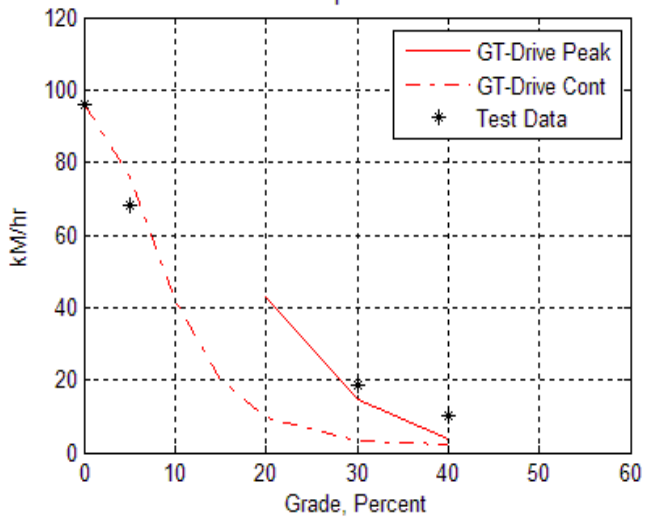
ACCELERATION



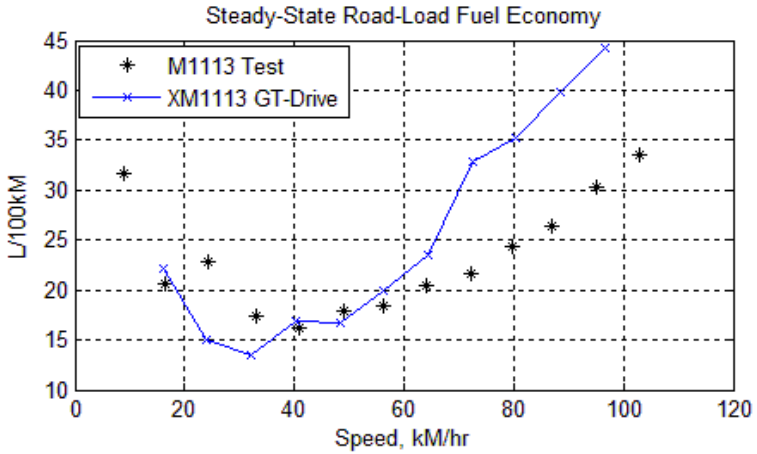


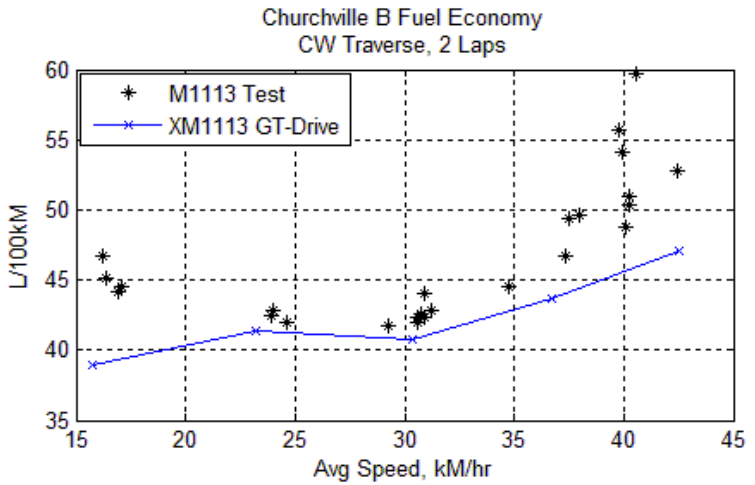
GRADEABILITY

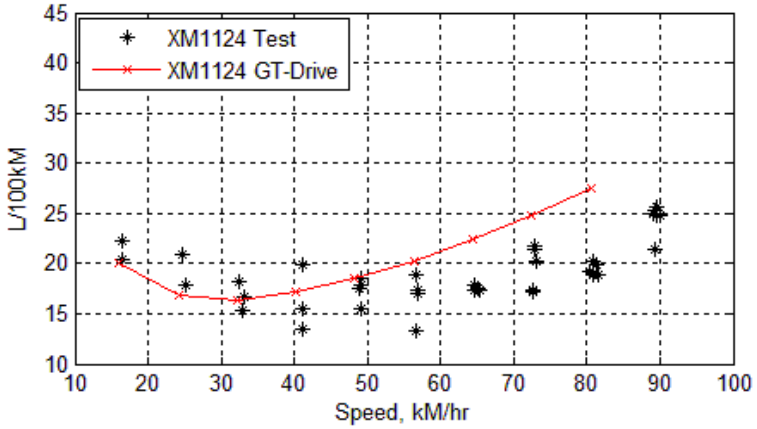


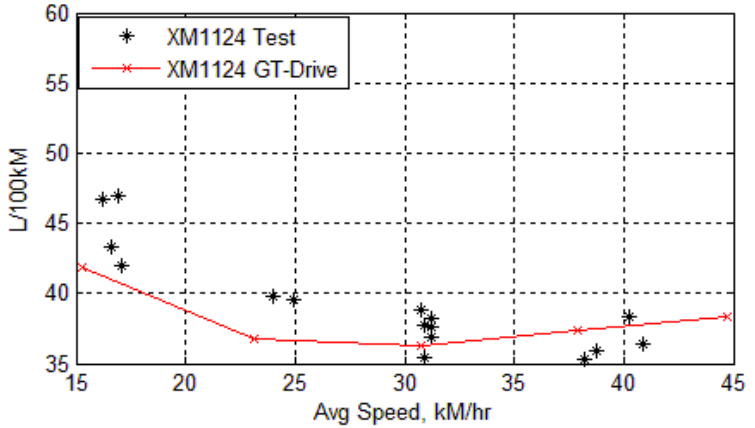


GT-Drive Vehicle Fuel Consumption





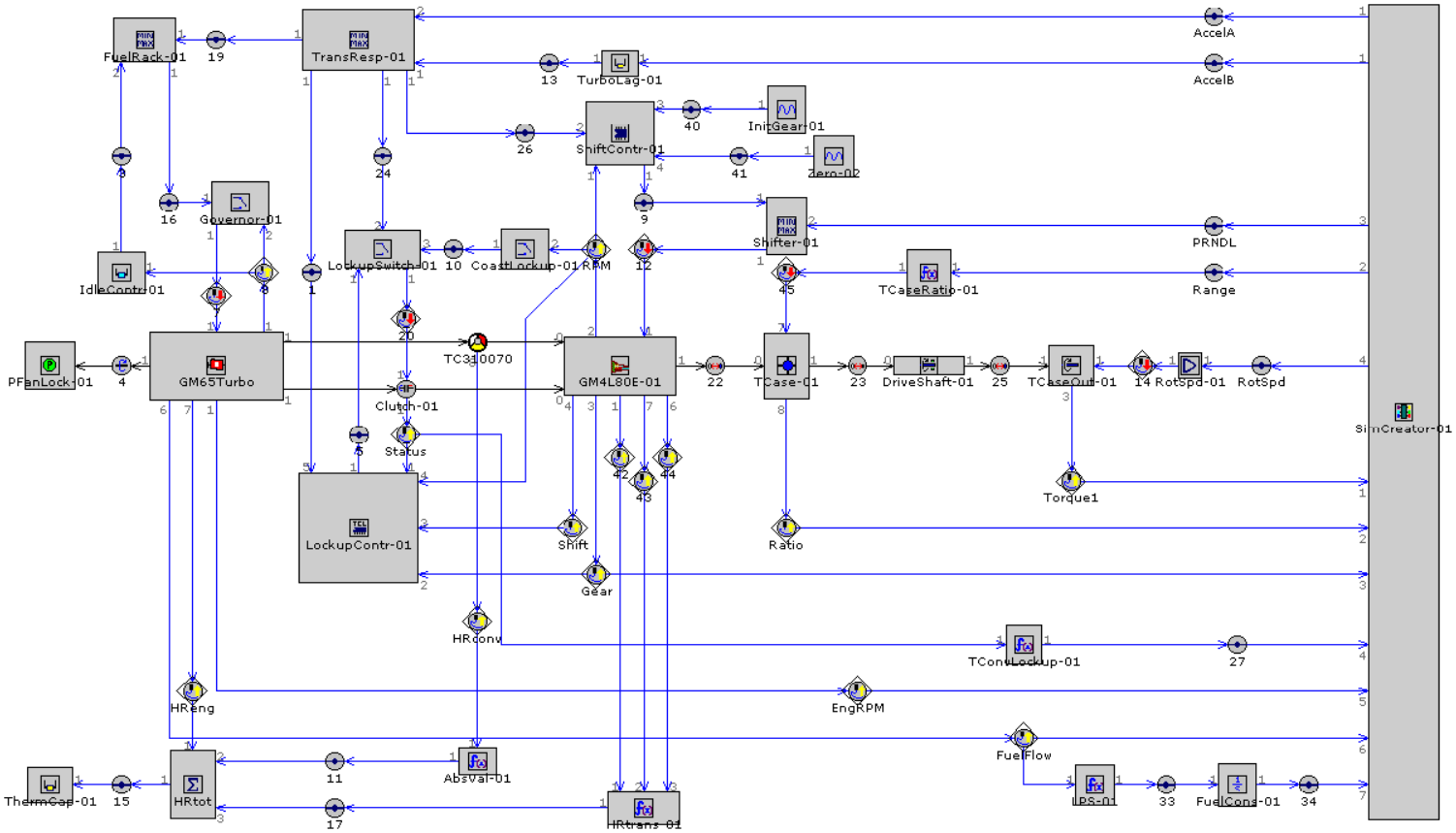




GT-Drive Power-Train Preparation

- Remove GT-Drive Vehicle Components:
  - Vehicle Body, Axles, etc.
  - Road, Environment
  - PID Driver
- Add Components
  - “SpeedBoundaryRot” at T-Case Output
    - Imposes Rotational Speed from SimCreator drive-line
    - Applies Reaction Torque to drive-line
  - SimuLink Wiring Harness
    - Driver Interface
    - Vehicle / Power-Train Model Interface
    - Information Channels
- Create Real-Time .dat file

GT-Drive M1113 Power-Train Model

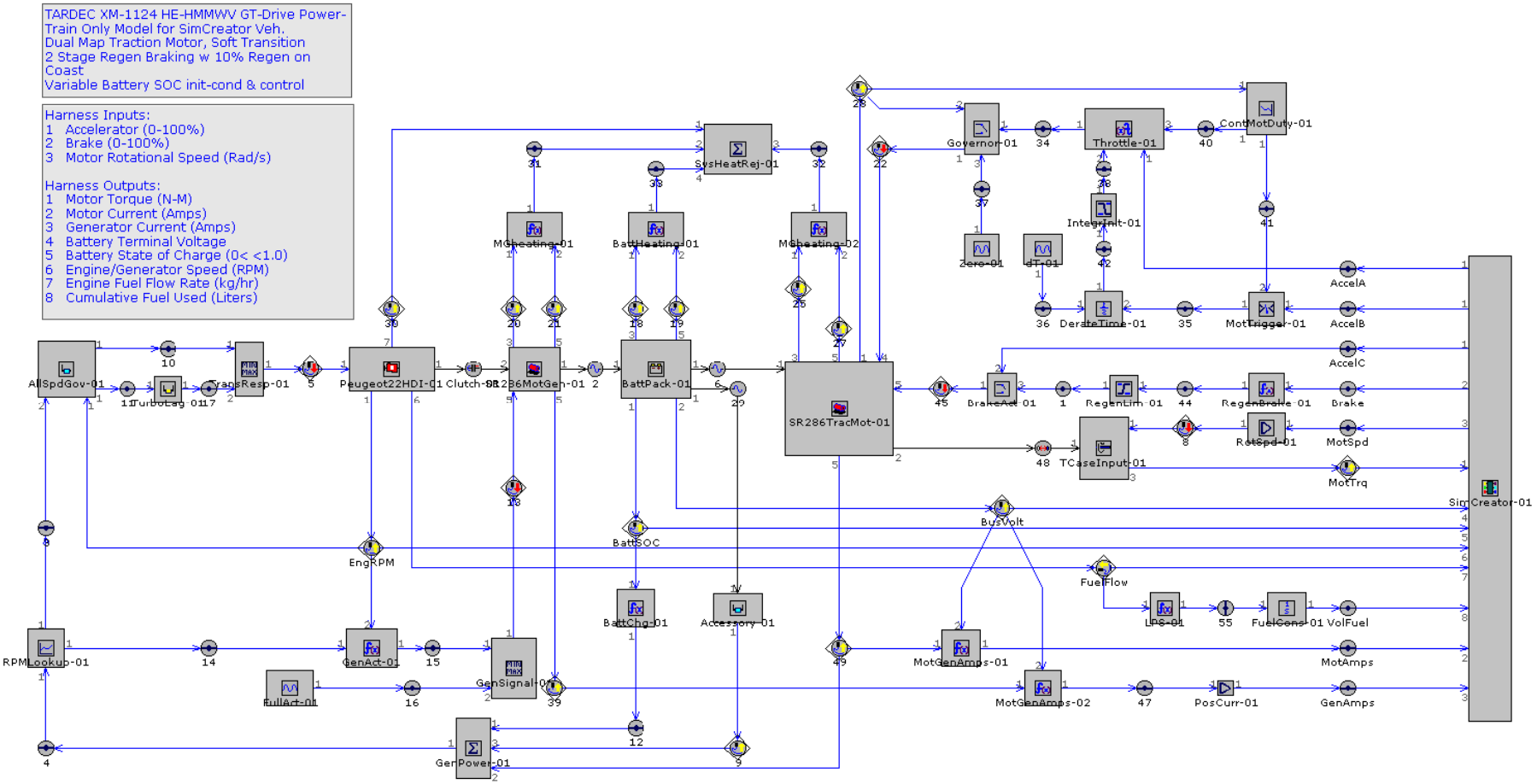


TARDEC GT-Drive M1113 HMMWV Power-Train Only Model for SimCreator Vehicle Dynamics Model Improved Engine Braking through Conv-Lockup in Coast-Down

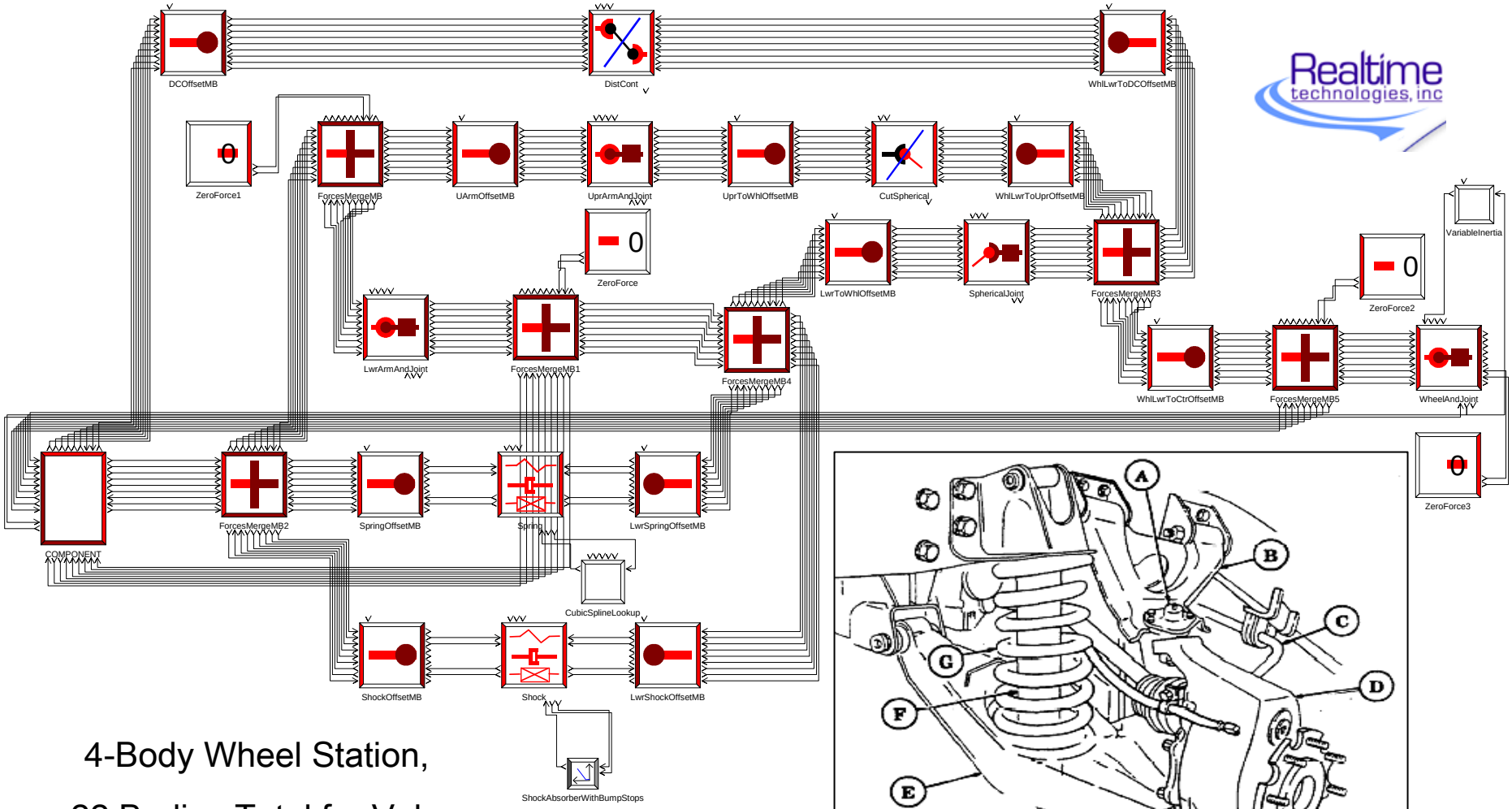
Harness Inputs:
1 Accelerator (0-100%)
2 T-Case Range (0=Low, 1=High)
3 PRNDL (1 - 4)
4 T-Case Output Speed (Rad/s)

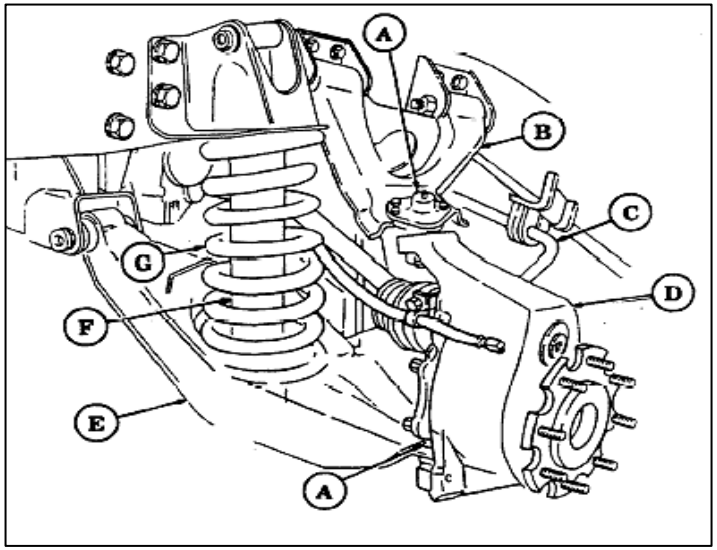
Harness Outputs:
1 Driveline Torque (N-M)
2 T-Case ratio
3 Transmission Gear
4 Converter Lockup Status
5 Engine/Generator Speed (RPM)
6 Engine Fuel Flow Rate (kg/hr)
7 Cumulative Fuel Used (Liters)

GT-Drive XM1124 Power-Train Model



SimCreator Suspension Model



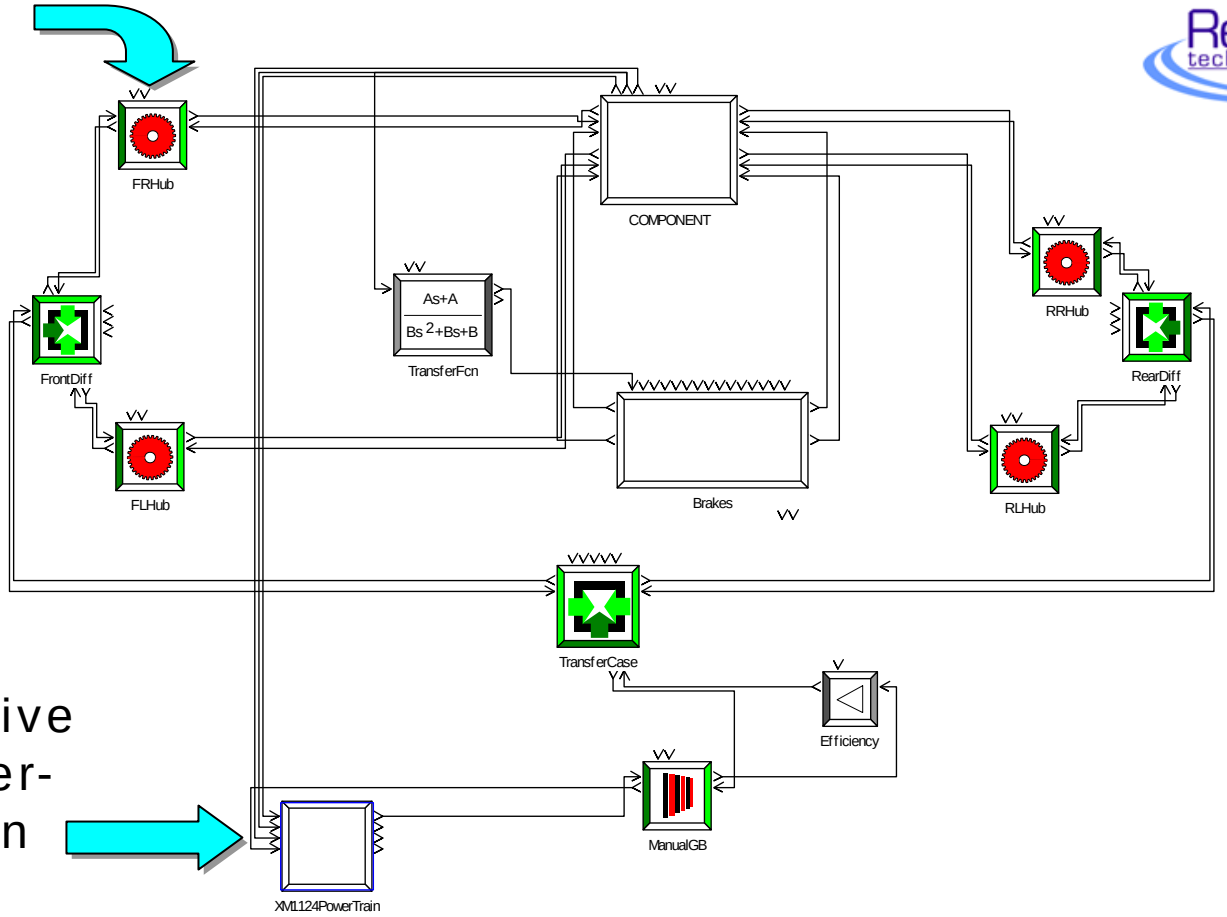


4-Body Wheel Station,

22 Bodies Total for Veh.

SimCreator Vehicle Model

Wheel Station

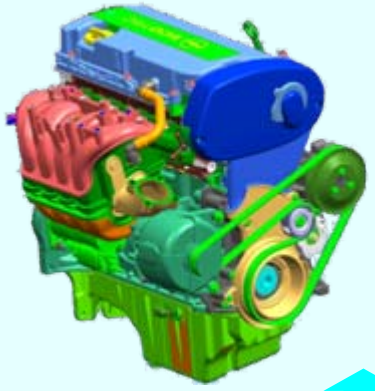


GT-Drive Power-Train

GT-Drive / SimCreator Integration

GT-DRIVE

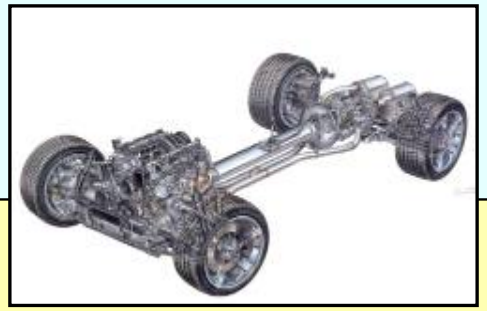
MAP BASED or "MEAN-VALUE" ENGINE MODEL



Virtual Vehicle Simulation

POWERTRAIN CONTROLS

DRIVELINE COMPONENTS



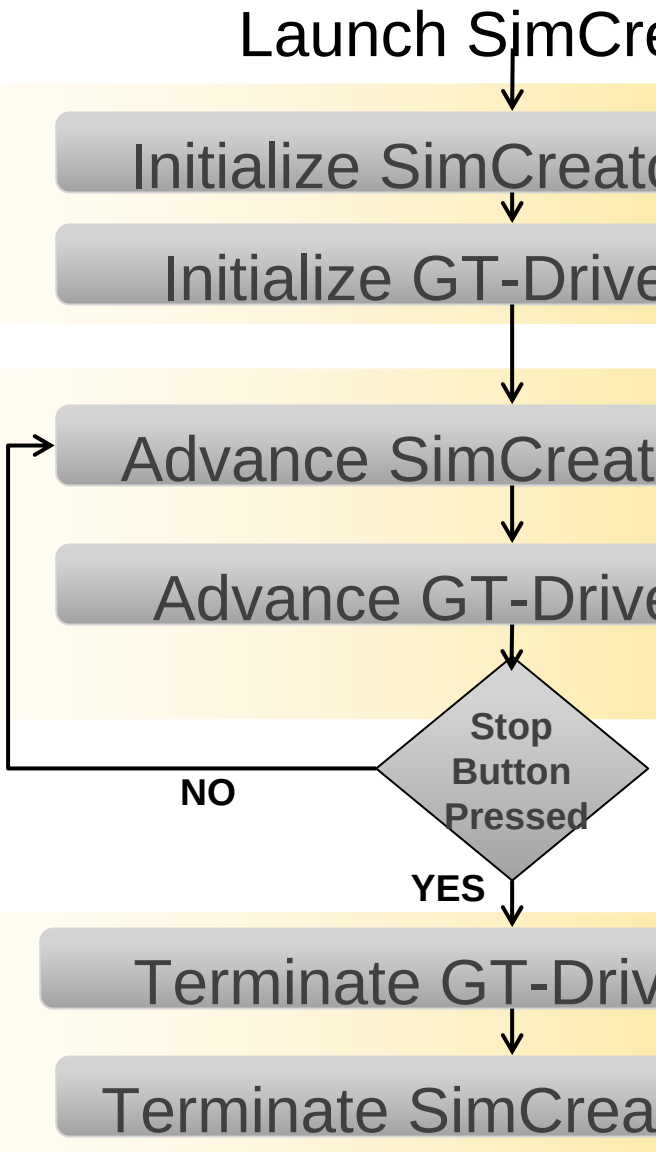
SimCreator

VEHICLE BODY

ROAD and ENVIRONMENT

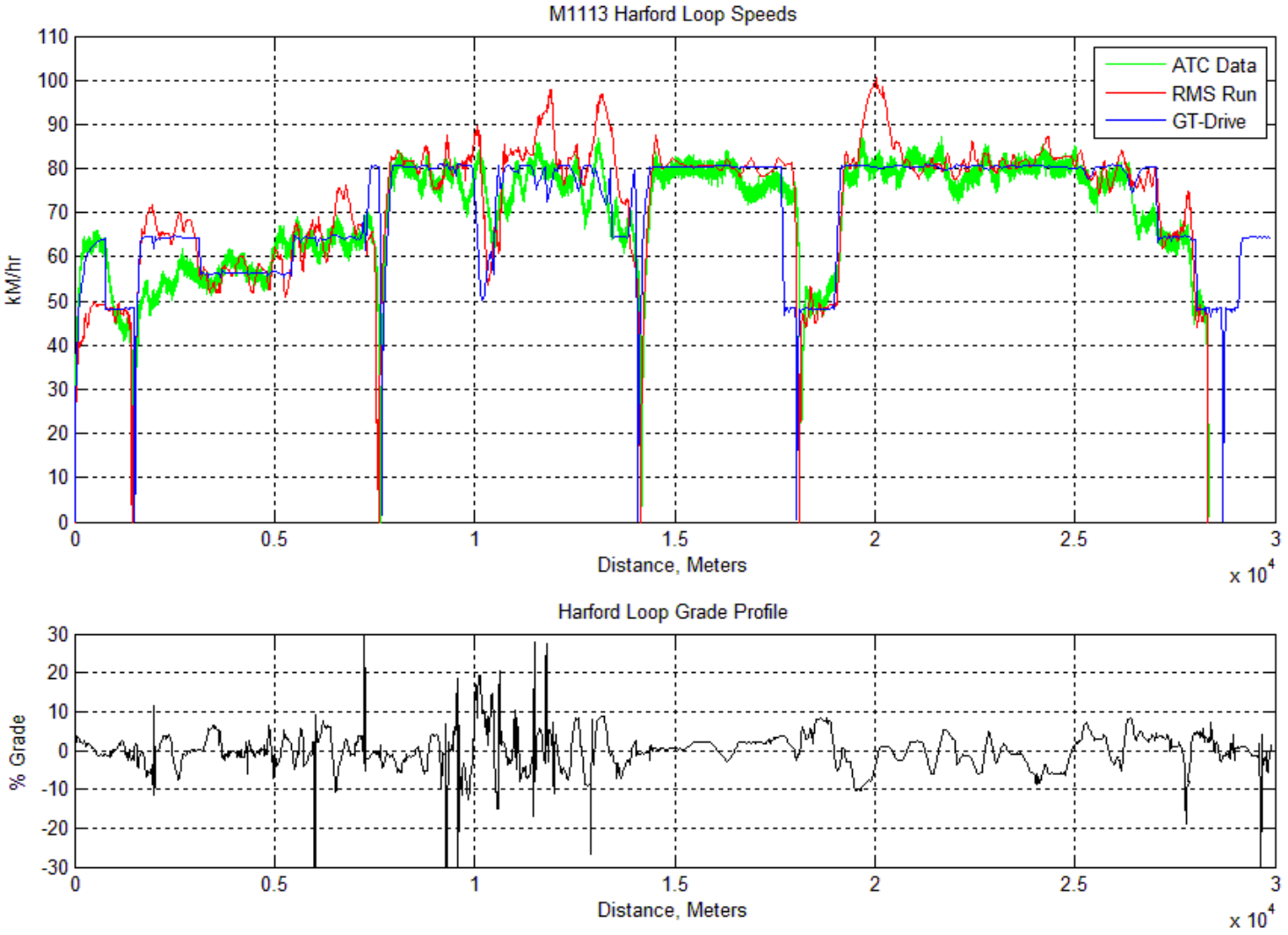
DRIVER

- Initialization
- Runtime
- Termination

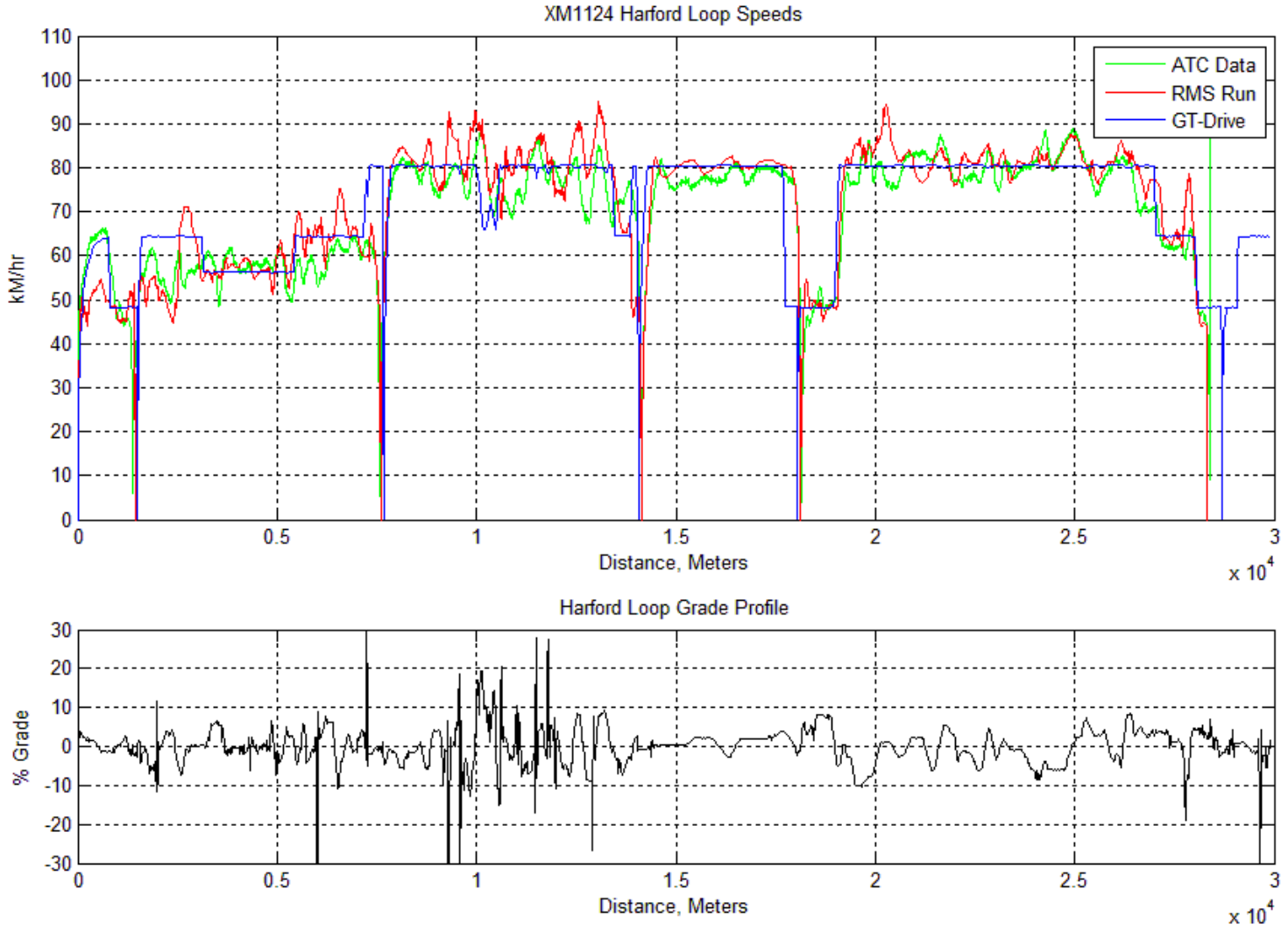


- Integration achieved in Linux by dynamically linking the GT-SUITE-RT solver library in the model executable.
- RT Capability achieved through:
  - *Euler ODE solver for speedup*
  - *Extra “bulk” in standard solver removed*
  - *No RLT’s, plots or other output stored*

Course Results



Course Results



Fuel Consumption Results

Test Course	HMMWV Variant	Lap Speed Mph (kM/hr)	APG-Test L/100kM	GT-Drive L/100kM	RMS-Simulation L/100kM
Munson Fuel Loop	M1113	10 (16.1)	25.85	18.20	16.01
		15 (24.1)	23.53	19.90	16.97
		20 (32.2)	22.19	20.64	18.57
		25 (40.2)	22.41	23.11	21.19
		30 (48.3)	24.25	25.31	24.04
	XM1124	10 (16.1)	22.41	25.94	20.60
		15 (24.1)	21.78	22.79	18.29
		20 (32.2)	20.82	22.62	19.08
		25 (40.2)	20.46	23.24	20.71
		30 (48.3)	22.62	24.47	23.91
Churchville Hilly X-Country	M1113	10 (16.1)	45.24	38.94	35.11
		15 (24.1)	42.78	41.38	36.53
		20 (32.2)	42.78	40.71	36.56
		25 (40.2)	43.57	43.71	39.74
	XM1124	10 (16.1)	42.78	41.85	30.44
		15 (24.1)	39.21	36.72	28.16
		20 (32.2)	36.76	36.30	27.91
		25 (40.2)	38.57	37.42	30.55
Harford Loop	M1113	Posted Limits	24.76	31.17	22.41
	XM1124		22.19	29.55	18.75

Conclusion

- GT-Drive vehicle models using typical component data accurately predict vehicle full-throttle performance.
- Fuel Economy results more approximate: sensitive to component spin-losses, accessory loads, etc.
- GT-Drive power-trains exportable for use in multi-body vehicle-dynamic and human-in-the-loop co-simulations.
  - Evaluate automotive performance of virtual vehicles
  - Allow pre-prototype user evaluation
  - Collect duty-cycle data for simulated mission scenarios